ULTRASONIC IMAGING METHOD AND ULTRASONIC DIAGNOSTIC APPARATUS

BACKGROUND OF THE INVENTION

The present invention relates to an ultrasonic imaging method and ultrasonic diagnostic apparatus, and more particularly to an ultrasonic imaging method and ultrasonic diagnostic apparatus by which comparison between a previously acquired reference image and a real-time image currently being acquired can be suitably made.

Conventionally, there has been known an ultrasonic diagnostic apparatus that stores a reference image, reads out the reference image, and displays the reference image with a real-time image superimposed or arranged side by side. (For example, see Patent Document 1).

[Patent Document 1]

Japanese Patent Application Laid Open No. 2000-300557 (Claim 1, [0003]).

In the conventional ultrasonic diagnostic apparatus, however, no consideration is given to possible difference between the scan conditions for the reference image and for the real-time image.

If a difference exists between the scan conditions, a problem arises in that a region unchanged from the past to the present looks as if it were changed or a region changed from the past to the present looks as if it were unchanged.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide an ultrasonic imaging method and ultrasonic diagnostic apparatus by which comparison between a previously acquired reference image and a real-time image currently being acquired can be suitably made by making their scan conditions the same.

In a first aspect, the present invention provides an ultrasonic imaging method characterized in comprising: storing a reference image and a scan

condition therefor; reading said reference image and said scan condition; setting said scan condition and acquiring a real-time image; and displaying said reference image and said real-time image side by side.

According to the ultrasonic imaging method of the first aspect, a scan condition for a reference image is stored, the scan condition is read out to acquire a real-time image, and the reference image and real-time image are displayed side by side. Thus, images acquired with the same scan condition can be compared; for example, a reference image acquired before medical treatment and a real-time image after medical treatment can be compared to accurately estimate the effect of the medical treatment.

In a second aspect, the present invention provides the ultrasonic imaging method having the aforementioned configuration, characterized in comprising: calculating a correlation coefficient between said reference image and said real-time image throughout or partially; and displaying the calculated correlation coefficient.

According to the ultrasonic imaging method of the second aspect, a correlation coefficient between corresponding regions in the reference image and real-time image is calculated and displayed. Thus, the degree of difference between the reference image and real-time image can be objectively evaluated.

In a third aspect, the present invention provides an ultrasonic imaging method characterized in comprising: storing a reference image and a scan condition therefor; reading said reference image and said scan condition; setting said scan condition and acquiring a plurality of real-time images at different scan plane angles; calculating a correlation coefficient between said reference image and each of said real-time images throughout or partially; and displaying said reference image and said real-time image having the highest correlation coefficient side by side.

According to the ultrasonic imaging method of the third aspect, a plurality of real-time images are acquired at different scan plane angles, and the real-time

image having the highest correlation coefficient with respect to the reference image is selected and displayed. As this makes it permissible to put the ultrasonic probe against a subject somewhat imprecisely, it reduces the work load on a human operator.

In a fourth aspect, the present invention provides the ultrasonic imaging method having the aforementioned configuration, characterized in comprising: displaying said highest correlation coefficient.

According to the ultrasonic imaging method of the fourth aspect, a correlation coefficient between corresponding regions of the reference image and real-time image being displayed is presented. Thus, the degree of difference between the reference image and real-time image being displayed can be objectively evaluated.

In a fifth aspect, the present invention provides the ultrasonic imaging method having the aforementioned configuration, characterized in comprising: displaying in a hold manner the maximum value of the correlation coefficient from the beginning of acquisition of the real-time image up to the present.

According to the ultrasonic imaging method of the fifth aspect, since the maximum value of the correlation coefficient up to the present is displayed in a hold manner, the way in which the ultrasonic probe is put against the subject can be adjusted to maximize the correlation coefficient and thereby maintain the best way.

In a sixth aspect, the present invention provides the ultrasonic imaging method having the aforementioned configuration, characterized in comprising: calculating a correlation coefficient for a region outside of a region of interest defined in said reference image or in said real-time image.

According to the ultrasonic imaging method of the sixth aspect, if a region to be treated is defined as a region of interest, for example, a portion which changes between before and after medical treatment is excluded in the calculation of a correlation coefficient, and therefore, the correlation coefficient between the

reference image and real-time image can be accurately calculated.

In a seventh aspect, the present invention provides the ultrasonic imaging method having the aforementioned configuration, characterized in comprising: calculating a correlation coefficient for a correlation comparison region defined in said reference image or in said real-time image.

According to the ultrasonic imaging method of the seventh aspect, if a region other than a region to be treated is defined as a correlation comparison region, for example, a portion which changes between before and after medical treatment is excluded in the calculation of a correlation coefficient, and therefore, the correlation coefficient between the reference image and real-time image can be accurately calculated.

In an eighth aspect, the present invention provides the ultrasonic imaging method having the aforementioned configuration, characterized in comprising: displaying said reference image and said real-time image superimposed in response to a command by an operator.

According to the ultrasonic imaging method of the eighth aspect, the reference image and real-time image can be displayed superimposed to facilitate estimation of the presence or degree of change.

In a ninth aspect, the present invention provides the ultrasonic imaging method having the aforementioned configuration, characterized in comprising: storing a measurement result for a target region in said reference image; and reading said measurement result and displaying it when displaying said reference image.

According to the ultrasonic imaging method of the ninth aspect, since one can know a pre-treatment value of, for example, the diameter or area of a region to be treated, the effect of treatment can be numerically estimated.

In a tenth aspect, the present invention provides the ultrasonic imaging method having the aforementioned configuration, characterized in comprising: storing said reference image and said scan condition in a server on a network.

According to the ultrasonic imaging method of the tenth aspect, if one who has stored a reference image and a scan condition therefor in a server makes the server public, others can read and use the reference image and scan condition.

In an eleventh aspect, the present invention provides an ultrasonic diagnostic apparatus characterized in comprising: an ultrasonic probe; transmitting/receiving means for driving said ultrasonic probe to transmit ultrasonic pulses into a subject and receive ultrasonic echoes from inside the subject and outputting received data; ultrasonic image producing means for producing an ultrasonic image from the resulting received data; reference image storage means for storing a reference image; scan condition storage means for storing a scan condition for the reference image; automatic scan condition setting means for reading said scan condition and setting it; ultrasonic image display means for reading said reference image and displaying said reference image and a real-time image side by side.

According to the ultrasonic diagnostic apparatus of the eleventh aspect, the ultrasonic imaging method of the first aspect can be suitably implemented.

In a twelfth aspect, the present invention provides the ultrasonic diagnostic apparatus having the aforementioned configuration, characterized in comprising: correlation coefficient calculating means for calculating a correlation coefficient between said reference image and said real-time image throughout or partially; and correlation coefficient display means for displaying the calculated correlation coefficient.

According to the ultrasonic diagnostic apparatus of the twelfth aspect, the ultrasonic imaging method of the second aspect can be suitably implemented.

In a thirteenth aspect, the present invention provides an ultrasonic diagnostic apparatus characterized in comprising: an ultrasonic probe; transmitting/receiving means for driving said ultrasonic probe to transmit ultrasonic pulses into a subject and receive ultrasonic echoes from inside the subject and outputting received data; ultrasonic image producing means for producing an ultrasonic image from the

resulting received data; reference image storage means for storing a reference image; scan condition storage means for storing a scan condition for the reference image; automatic scan condition setting means for reading said scan condition and setting it; scan plane angular scanning means for acquiring a plurality of real-time images at different scan plane angles; correlation coefficient calculating means for calculating a correlation coefficient between said reference image and each of said real-time images throughout or partially; and ultrasonic image display means for displaying said reference image and said real-time image having the highest correlation coefficient side by side.

According to the ultrasonic diagnostic apparatus of the thirteenth aspect, the ultrasonic imaging method of the third aspect can be suitably implemented.

In a fourteenth aspect, the present invention provides the ultrasonic diagnostic apparatus having the aforementioned configuration, characterized in comprising: correlation coefficient display means for displaying said highest correlation coefficient.

According to the ultrasonic diagnostic apparatus of the fourteenth aspect, the ultrasonic imaging method of the fourth aspect can be suitably implemented.

In a fifteenth aspect, the present invention provides the ultrasonic diagnostic apparatus having the aforementioned configuration, characterized in comprising: correlation coefficient maximum value display means for displaying in a hold manner the maximum value of the correlation coefficient from the beginning of acquisition of the real-time image up to the present.

According to the ultrasonic diagnostic apparatus of the fifteenth aspect, the ultrasonic imaging method of the fifth aspect can be suitably implemented.

In a sixteenth aspect, the present invention provides the ultrasonic diagnostic apparatus having the aforementioned configuration, characterized in that: said correlation coefficient calculating means calculates a correlation coefficient for a region outside of a region of interest defined in said reference image or in said real-time image.

According to the ultrasonic diagnostic apparatus of the sixteenth aspect, the ultrasonic imaging method of the sixth aspect can be suitably implemented.

In a seventeenth aspect, the present invention provides the ultrasonic diagnostic apparatus having the aforementioned configuration, characterized in that: said correlation coefficient calculating means calculates a correlation coefficient for a correlation comparison region defined in said reference image or in said real-time image.

According to the ultrasonic diagnostic apparatus of the seventeenth aspect, the ultrasonic imaging method of the seventh aspect can be suitably implemented.

In an eighteenth aspect, the present invention provides the ultrasonic diagnostic apparatus having the aforementioned configuration, characterized in comprising: combined-display means for displaying said reference image and said real-time image superimposed in response to a command by an operator.

According to the ultrasonic diagnostic apparatus of the eighteenth aspect, the ultrasonic imaging method of the eighth aspect can be suitably implemented.

In a nineteenth aspect, the present invention provides the ultrasonic diagnostic apparatus having the aforementioned configuration, characterized in comprising: measurement result storage means for storing a measurement result for a target region in said reference image; and measurement result display means for reading said measurement result and displaying it when displaying said reference image.

According to the ultrasonic diagnostic apparatus of the nineteenth aspect, the ultrasonic imaging method of the ninth aspect can be suitably implemented.

In a twentieth aspect, the present invention provides the ultrasonic diagnostic apparatus having the aforementioned configuration, characterized in that: said reference image storage means and said scan condition storage means reside in said ultrasonic diagnostic apparatus itself, and in addition, in a server on a network.

According to the ultrasonic diagnostic apparatus of the twentieth aspect, the

ultrasonic imaging method of the tenth aspect can be suitably implemented. Moreover, the storage capacity of the ultrasonic diagnostic apparatus itself need not to be increased, thus simplifying the configuration.

In a twenty-first aspect, the present invention provides the ultrasonic diagnostic apparatus having the aforementioned configuration, characterized in that: said reference image storage means and said scan condition storage means reside not in said ultrasonic diagnostic apparatus itself but in a server on a network.

According to the ultrasonic diagnostic apparatus of the twenty-first aspect, the ultrasonic imaging method of the tenth aspect can be suitably implemented. Moreover, the storage capacity of the ultrasonic diagnostic apparatus itself may be small, thus simplifying the configuration.

According to the ultrasonic imaging method and ultrasonic diagnostic apparatus of the present invention, comparison between a previously acquired reference image and a real-time image currently being acquired can be suitably made by making their scan conditions the same.

Further objects and advantages of the present invention will be apparent from the following description of the preferred embodiments of the invention as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram showing an ultrasonic diagnostic apparatus in accordance with a first embodiment.

Figure 2 is a flow chart showing operations and processes in storing a reference image by the ultrasonic diagnostic apparatus in accordance with the first embodiment.

Figure 3 is a flow chart showing operations and processes in acquiring a real-time image and comparing it with a reference image by the ultrasonic diagnostic apparatus in accordance with the first embodiment.

Figure 4 is an explanatory diagram showing a screen on which a reference image is displayed.

Figure 5 is an explanatory diagram showing a screen on which the reference image and a real-time image are displayed side by side.

Figure 6 is an explanatory diagram showing a screen on which a region of interest is specified in the reference image.

Figure 7 is an explanatory diagram showing a screen on which a region of interest is automatically defined in the real-time image.

Figure 8 is an explanatory diagram showing a screen on which a correlation coefficient is displayed.

Figure 9 is an explanatory diagram showing a screen on which the maximum correlation coefficient is displayed.

Figure 10 is an explanatory diagram showing a screen on which a measurement result is displayed.

Figure 11 is an explanatory diagram showing a screen on which the reference image and real-time image are displayed superimposed.

Figure 12 is an explanatory diagram showing a screen on which a correlation comparison region is defined in the reference image.

Figure 13 is a flow chart showing operations and processes in acquiring a real-time image and comparing it with a reference image by the ultrasonic diagnostic apparatus in accordance with a second embodiment.

Figure 14 is an explanatory diagram showing a plurality of scan planes with different angles.

DETAILED DESCRIPTION OF THE INVENTION

The present invention will now be described in more detail with reference to embodiments shown in the accompanying drawings.

- First Embodiment -

Figure 1 is a block diagram of an ultrasonic diagnostic apparatus 100 in

accordance with a first embodiment.

The ultrasonic diagnostic apparatus 100 comprises an ultrasonic probe 1, a transmitting/receiving section 2 for driving the ultrasonic probe 1 to conduct a scan in a scan plane and output an acoustic line signal, a signal processing section 3 for generating an ultrasonic image signal based on the acoustic line signal, a display control section 9 for generating image data from the ultrasonic image signal, a display section 5 for displaying an ultrasonic image based on the image data, a data storage section 6 for storing the generated image data and the like, an operating section 7 provided with a keyboard and pointing device for an operator to input commands, an interface section 8 for connection with a server S via an external network N, and a control section 9 including a correlation calculating section 9a for calculating a correlation coefficient between two ultrasonic images, and controlling the overall operation.

Figure 2 is a flow chart showing operations and processes in storing a reference image using the ultrasonic diagnostic apparatus 100.

At Step S1, an operator operates the operating section 7 and prescribes a scan condition.

At Step S2, the operator puts the ultrasonic probe 1 against a subject so that a region to be treated is contained in a scan plane, and performs a scan.

At Step S3, the ultrasonic diagnostic apparatus 100 produces an ultrasonic image, and displays it at the display section 5.

At Step S4, after an ultrasonic image serving as a reference image has been obtained, the operator uses a measurement function of the ultrasonic diagnostic apparatus 100 to measure the size or area of the region to be treated in the reference image.

At Step S5, the ultrasonic diagnostic apparatus 100 stores the reference image, scan condition and measurement result therefor in both or one of the data storage section 6 and server S on the network N in response to a command by the operator.

Figure 3 is a flow chart showing operations and processes in acquiring a real-time image and comparing it with the reference image using the ultrasonic diagnostic apparatus 100.

At Step R1, the ultrasonic diagnostic apparatus 100 reads the reference image, scan condition and measurement result therefor from the data storage section 6 or server S in response to a command by the operator. The reading may be made on a reference image and a scan condition therefor stored on the server S and made public by a third party.

At Step R2, the ultrasonic diagnostic apparatus 100 creates two display sections on a screen, as shown in Figure 4, and displays a reference image G0, a scan condition J0, and a measurement result D0 in one of the sections. T0 designates a region to be treated before medical treatment.

At Step R3, the ultrasonic diagnostic apparatus 100 sets the read scan condition as the current scan condition.

At Step R4, the operator puts the ultrasonic probe 1 against the subject so that the region to be treated is contained in a scan plane, and performs a scan.

At Step R5, the ultrasonic diagnostic apparatus 100 produces an ultrasonic image, and as shown in Figure 5, displays it as a real-time image G1 in the other section on the screen. T1 designates the region to be treated after medical treatment.

At Step R6, the operator specifies a region of interest ROI0 in the reference image G0 to encompass the region to be treated T0, as shown in Figure 6.

At Step R7, the ultrasonic diagnostic apparatus 100 automatically defines a region of interest ROI1 in the real-time image G1 corresponding to the region of interest ROI0 in the reference image G0, as shown in Figure 7.

At Step R8, the ultrasonic diagnostic apparatus 100 calculates a correlation coefficient between a portion outside of the region of interest ROI0 in the reference image G0 and a portion outside of the region of interest ROI1 in the real-time image G1, and displays the correlation coefficient K on the screen, as

shown in Figure 8.

At Step R9, the ultrasonic diagnostic apparatus 100 updates a maximum correlation coefficient K_{max} that holds the maximum value of the correlation coefficient from the beginning of acquisition of the real-time image up to the present, and displays the maximum correlation coefficient K_{max} on the screen, as shown in Figure 9.

At Step R10, the ultrasonic diagnostic apparatus 100 goes to Step R11 upon an operation for measurement by the operator; otherwise, to Step R12.

At Step R11, the ultrasonic diagnostic apparatus 100 measures the size or area of the portion specified by the operator, and displays a measurement result D1, as shown in Figure 10. The flow then proceeds to Step R12.

At Step R12, the ultrasonic diagnostic apparatus 100 goes to Step R13 if the operator issues a command to superimpose the images; otherwise, to Step R14.

At Step R13, the ultrasonic diagnostic apparatus 100 displays a superimposed image G2 in which the reference image G0 is superimposed with the real-time image R1, as shown in Figure 11. If the operator issues a command to release the superimposition, the display of superimposed image G2 is restored to the display of the reference image G0, and the flow proceeds to Step R14.

At Step R14, the ultrasonic diagnostic apparatus 100 terminates the processing if the operator issues a termination command; otherwise, goes to Step R15.

At Step R15, the operator performs a scan while adjusting the way in which the ultrasonic probe 1 is put against the subject so that the correlation coefficient K becomes equal to the maximum correlation coefficient K_{max}.

At Step R16, the ultrasonic diagnostic apparatus 100 produces an ultrasonic image and displays it as a real-time image G1 in the other section on the screen. The flow then goes back to Step R8.

In the ultrasonic diagnostic apparatus 100 in accordance with the first embodiment, since a real-time image is acquired with the same scan condition as

that of a reference image, the reference image and real-time image can be suitably compared.

Moreover, as shown in Figure 12, correlation comparison regions A0 and A1 may be defined outside of the regions of interest ROI0 and ROI1 to calculate a correlation coefficient between the correlation comparison regions A0 and A1. By defining the correlation comparison region A0 and A1 to calculate a correlation coefficient, the processing load in the correlation calculation is reduced.

- Second Embodiment -

The configuration of the ultrasonic diagnostic apparatus in accordance with a second embodiment is similar to that of the ultrasonic diagnostic apparatus 100 in the first embodiment. However, a two-dimensional array ultrasonic probe 1′ shown in Figure 14 is used.

Figure 13 is a flow chart showing operations and processes in acquiring a real-time image and comparing it with a reference image by the ultrasonic diagnostic apparatus in accordance with the second embodiment.

Step R1 — Step R7 are the same as those shown in Figure 3.

At Step R21, the ultrasonic diagnostic apparatus 100 conducts imaging in a plurality of scan planes P1 — P5 with different angles, as shown in Figure 14, to produce a plurality of real-time images.

At Step R22, the ultrasonic diagnostic apparatus 100 calculates a correlation coefficient between a portion outside of the region of interest ROI0 in the reference image G0 and a portion outside of the region of interest in each of the real-time images.

At Step R23, the real-time image having the highest correlation coefficient is selected and displayed in the other section on the screen. Its correlation coefficient K is also displayed.

Step R9 — Step R13 are the same as those shown in Figure 3.

At Step R14′, if the operator issues a termination command, the ultrasonic

diagnostic apparatus 100 terminates the processing; otherwise, goes back to Step R21.

In the ultrasonic diagnostic apparatus in accordance with the second embodiment, since a plurality of real-time images are acquired at different scan plane angles, and the real-time image having the highest correlation coefficient with respect to the reference image is selected and displayed, it is permissible to put the ultrasonic probe 1′ against a subject somewhat imprecisely, and, therefore, the work load on a human operator is reduced.

Instead of electronically changing the scan plane angle using the two-dimensional array ultrasonic probe 1′, the angle of the regular ultrasonic probe 1 may be mechanically changed.

- Other Embodiments -

While comparison is made between an ultrasonic image before medical treatment as a reference image and a real-time image after medical treatment in the first and second embodiments, comparison may be made between an exemplary ultrasonic image acquired by a teacher or the maker of the ultrasonic diagnostic apparatus as a reference image and a real-time image acquired by a student or user. This makes it easier for the student or user to learn the skill of scanning.

Many widely different embodiments of the invention may be configured without departing from the spirit and the scope of the present invention. It should be understood that the present invention is not limited to the specific embodiments described in the specification, except as defined in the appended claims.